電気材料技術雑誌　第20巻第２号
J. Soc. Elect. Mat. Eng.　Vol.20,　No.2　２０１１

Randomness of Fingerprint Texture Pattern in Chiral Nematic Phase and Its Application

Keizo Nakayama[1] and Junji Ohtsubo[2]

[1]*Department of Electric and Electronic Engineering, Faculty of Science and Engineering, Kinki University, 3-4-1 Kowakae, Higashi-Osaka, Osaka 577-8502, Japan*

[2]*Department of Systems Engineering, Faculty of Engineering, Shizuoka University, 3-5-1 Johoku, Naka-ku, Hamamatsu, Shizuoka 432-8561, Japan*

E-mail: keizo@ele.kindai.ac.jp

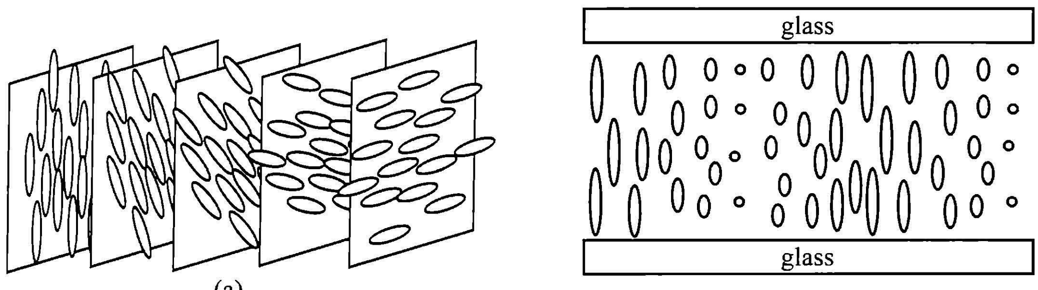
INTRODUCTION

Fingerprint texture in chiral nematic phase

There are many liquid crystal phases, in which various kinds of molecular orientations occur. Under polarization observation, textures reflecting on molecular orientation can be visible. The molecular orientation depends on a combination of liquid crystal phases and glass surface conditions, and then the textures depend on it too. In chiral nematic (N*) or cholesteric phases, molecules make a helical orientation structure as shown in Fig. 1(a). In a sandwich cell with a homeotropic surface treatment, the helix axis is parallel to the glass substrates as shown in Fig. 1(b) and a stripe pattern, which is called fingerprint texture, is observed using a polarizing microscope. In fact, the stripe patterns with the uncontrolled helix axis are complex and look like human fingerprints. As far as we know, there is little research about application of the random pattern's texture, though these textures are used mainly as the information for identification of the phase of materials using a polarizing microscope.

Application of natural randomness

Natural randomness is certain uncontrollable variations in features of some natural materials or products. This natural randomness is difficult to apply to industrial applications because homogeneous products are generally sought after. In the area of security, however, applications of information from natural randomness have been actively researched. For example, the following have been studied for security devices providing unique intification information: three-dimensional random patterns of polymer fibers in nonwoven fabric,[1] speckle patterns from a transparent inhomogeneous medium,[2,3] inhomogeneous emission patterns of a polymer light-emitting device,[4] and reflectance patterns from



(a)　　(b)

Figure 1: Chiral nematic phases; (a) helical structure, (b) orientation in a homeotropic cell.

the random rough surface of the product itself,[5,6] i.e. papers or plastic. Specifically, this random information has the potential to act as a fingerprint for vitally important artificial products, such as credit cards. For this application, uncontrollable features play an important role in assuring uniqueness.

In this paper, we will discuss the randomness of fingerprint texture pattern in detail and then its application to security devices we have proposed.[7]

EXPERIMENTAL

The liquid crystal mixture with the N* phase used in this study was a UV-curable liquid crystal (UCL-001-K1, DIC Corp.) doped with chiral dopant (S-811, Merck Ltd.) This mixture has an isotropic (Iso.)-N* phase sequence. The sandwich cell used was a commercial cell (E.H.C. Co. Ltd.) whose surfaces were treated to ensure homeotropic molecular alignment. Transmitted polarization observation was carried out using a polarizing microscope (ECLIPSE E600 POL, Nikon Corp.)

RESULTS AND DISCUSSION

Randomness of fingerprint texture

The randomness of fingerprint texture in the N* phase with homeotropic alignment was checked quantitatively by normalized cross-correlation using 10 different patterns. The 10 fingerprint texture patterns were captured repeatedly at the same place of the same cell following every re-orientation process by heat treatment. By heating the cell to the Iso. phase, the fingerprint texture disappears, and by cooling the cell to the N* phase again, the fingerprint texture appears again. Figure 2 shows two of 10 polarizing micrographs captured by a digital camera. These had an area of approximately 360 μm×270 μm and size of 1600×1200 pixels. Table 1 shows 45 correlation coefficients for all combinations of the 10 different patterns. The maximum of the 45 correlation coefficients was 0.11. These values are sufficiently low to confirm that the 10 fingerprint texture patterns are different.

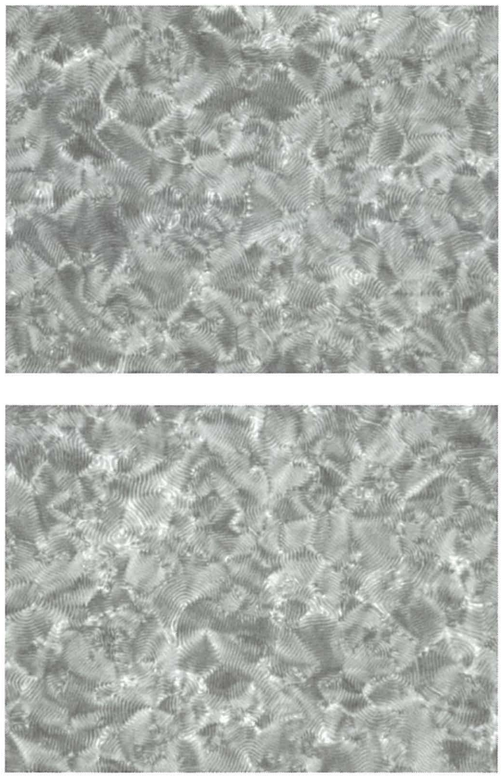


Figure 2: Polarizing microphotographs.

This experiment repeatedly used the same place of the same cell, creating the highest possibility of obtaining the same pattern. Therefore, this result suggests that samples fabricated under the same conditions cannot have the same pattern, just like human fingerprints. This uncontrollable property in the fingerprint texture is very convenient for security devices providing unique information.

Application for security devices

Molecules in liquid crystal phases can moved very easily. For application to security devices, which are embedded into artificial products and provide unique identification information, the patterns made by a molecular orientation must be fixed permanently.

Table 1: Normalized cross-correlation coefficients between 10 different patterns.

Pattern No.	1	2	3	4	5	6	7	8	9	10
1		0.03	0.02	0.03	0.01	-0.03	0.05	-0.01	-0.01	-0.01
2			0.03	0.08	0.09	0.03	0.07	0.04	0.01	0.02
3				0.07	0.05	0.03	0.09	0.02	0.07	0.03
4					0.05	0.06	0.06	0.05	-0.02	0.05
5						0.04	0.08	0.07	0.08	0.06
6							0.06	0.05	0.04	0.03
7								0.04	0.01	0.03
8									0.11	0.07
9										0.04
10										

Employing UV-curable liquid crystals and a photo polymerization technique can make permanent a molecular orientation. Thus, patterns of all fabricated liquid crystal devices can be fixed by irradiation of UV light.

We will summarize the basic scheme of the security system using the proposed devices, assuming that the products with significant authenticity are credit cards for instance. Many liquid crystal devices are made through an identical process. The additional work to give a different identifier pattern to each device is unnecessary because the pattern of the fingerprint texture has high randomness. Each card is embedded with the proposed device, and the information of the liquid crystal devices of each card is registered in a database prior to distribution. When the authenticity of a card is critical, the pattern of the proposed device in the card is read, and it is confirmed that this pattern is registered in the database.

Naturally, a higher level of security will be provided when this proposed system is used with the digital security technology currently in wide use.

SUMMARY

Randomness of fingerprint texture patterns in the N* phase and its application to security devices providing unique information for confirming authenticity were reported. This proposed device made use of uncontrolled random patterns of fingerprint texture in liquid crystal, although the normal liquid crystal devices mostly use controlled molecular alignment.

REFERENCES

[1] R. L. van Renesse, Proceedings of European Convention on Security and Detection (1995) 45.
[2] R. Pappu, B. Recht, J. Taylor, N. Gershenfeld, Science **297** (2002) 2026.
[3] O. Matoba, T. Sawasaki, K. Nitta, Appl. Opt. **47** (2008) 4400.
[4] K. Tada, M. Onoda, Jpn. J. Appl. Phys. **42** (2003) L1093.
[5] T. Haist, H. J. Tiziani, Opt. Comm. **147** (1998) 173.
[6] J. D. R. Buchanan, R. P. Cowburn, A.-V. Jausovec, D. Petit, P. Seem, G. Xiong, D. Atkinson, K. Fenton, D. A. Allwood, M. T. Bryan, Nature **436** (2005) 475.
[7] K. Nakayama, J. Ohtsubo, Mol. Cryst. Liq. Cryst. **516**, (2010) 253.